CHAETOGNATHS AND PTEROPODS AS BIOLOGICAL INDICATORS IN THE NORTH PACIFIC

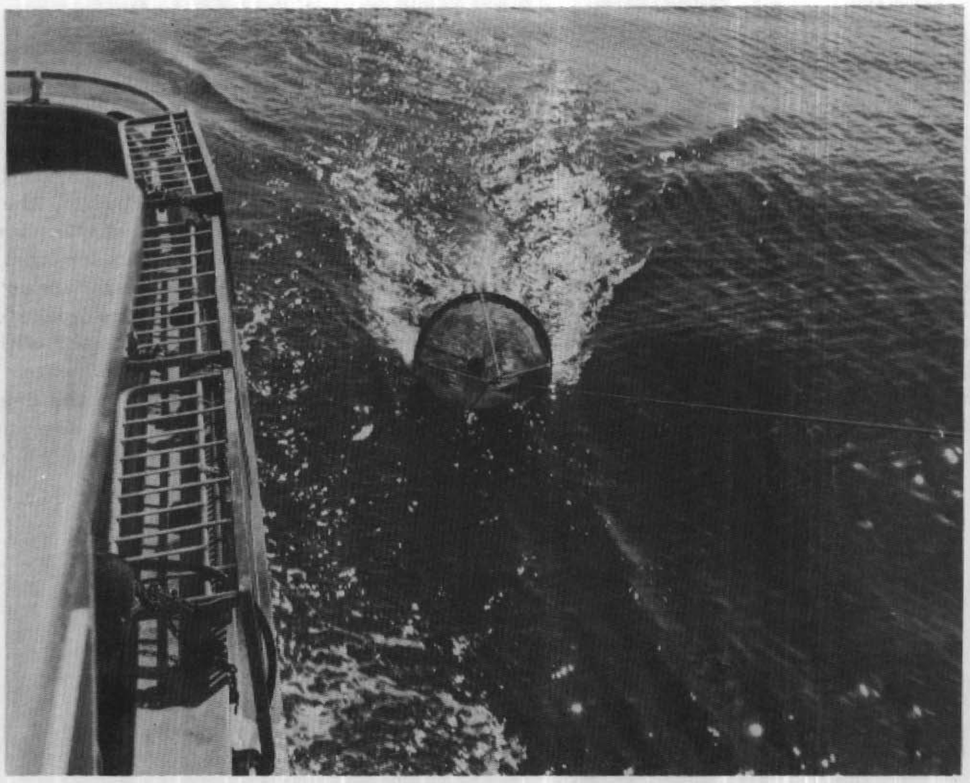
SPECIAL SCIENTIFIC REPORT-FISHERIES No. 215

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Explanatory Note

The series embodies results of investigations, usually of restricted scope, intended to aid or direct management or utilization practices and as guides for administrative or legislative action. It is issued in limited quantities for the official use of Federal, State or cooperating Agencies and in processed form for economy and to avoid delay in publication.

United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service



CHAETOGNATHS AND PTEROPODS AS BIOLOGICAL INDICATORS IN THE NORTH PACIFIC

By

Thomas S. Hida
Fishery Aid
Pacific Oceanic Fishery Investigations
Honolulu, T. H.

Special Scientific Report--Fisheries No. 215

WASHINGTON: June 1957

CONTENTS

ABSTRACT

In connection with investigations of potential albacore tuna fishing grounds, the distribution of chaetognaths and pteropods in the North Pacific was examined to determine whether any representatives of these groups could serve as biological indicators. The results indicated that the species of these groups, especially of the chaetognaths, segregated themselves into three "zones" which were termed the Subtropic, the Transition, and the Subarctic. Examination of the temperature-salinity relations coincident with the plankton tows showed the presence of three types of water with boundaries corresponding closely to the "zones". Higher catches, as number per unit of water strained, of chaetognaths and pteropods were obtained in the shallow (0 - 40 m.) hauls than in the deeper (0 - 140 m.) hauls both during the day and at night. Indications are that surface albacore are not confined to a particular type of water as defined by the faunal zones and the temperature-salinity characteristics.

ILLUSTRATIONS

CHAETOGNATHS AND PTEROPODS AS BIOLOGICAL INDICATORS IN THE NORTH PACIFIC

By

Thomas S. Hida
Fishery Aid
Pacific Oceanic Fishery Investigations
Honolulu, T. H.

This study is part of a general survey by the Fish and Wildlife Service of potential fishing grounds for albacore tuna in the North Pacific. The distribution and occurrence of the Chaetognatha and Pteropoda were examined to determine whether any representatives of these groups could serve as biological indicators, that is, supplement oceanographic data and help distinguish types of water in the North Pacific, thus assisting in locating and defining areas where albacore are likely to occur.

Indicator organisms have been used to identify water types in various parts of the world where the physical and chemical properties were not sufficiently definitive. The organisms must be readily identifiable and sufficiently abundant to be sampled in fair numbers. The chaetognaths and pteropods in the North Pacific fulfill these requirements.

The distribution and occurrence of chaetognaths and pteropods in the central North Pacific are not well known, and in this region have not been previously examined for possible use as indicators of different oceanographic environments. In other parts of the world, they have been employed for this purpose by several workers: Bigelow (1928), Russell (1939), Thomson (1947), Moore (1949), Fraser (1952), and others. As an example of the results, Fraser (1952) in his study of the Scottish area related chaetognaths, pteropods, and other organisms to changes in oceanographic conditions and cited Professor Meek's 1928 demonstration that *Sagitta setosa* dominated the waters along the Northumbrian coast when the southern North Sea water flooded the area and that *Sagitta elegans* was dominant when the northern North Sea water plus an Atlantic component moved into the region.

On the basis of species composition, the chaetognath and pteropod faunas of the central North Pacific were found to be naturally segregated into three regions, or "zones", which we have termed the Subtropic (a region of low zooplankton abundance), Transition (a region of variable abundance), and Subarctic (a region of high abundance) Zones. On the basis of temperature-salinity relations we can demonstrate the presence of three types of water, the Pacific Central Water mass, the North Pacific Current, and the Subarctic Water mass, with boundaries that coincide generally with those of the faunal zones established from the distribution of chaetognaths and pteropods.

The author is indebted to Thomas Austin and James McGary for their suggestions on interpretation of the oceanographic data.

SOURCE OF MATERIAL

The material for this study was collected in 1954-55 in an area extending latitudinally from 22°N. to 50°N. and longitudinally from 170°E. to 145°W. The samples were obtained in most cases with 1-meter nets of 30XXX-grit gauze in 30-minute oblique tows. A detailed description of the gear used and the method of hauling was given by King and Demond (1953). The cruise period, sampling depths, and numbers of samples examined for the various cruises were as follows: *Hugh M. Smith* cruise 25 (February 1955, 0 - 200 m., 8 samples); *Charles H. Gilbert* cruise 17 (September - November 1954, 0 - 100 m., 40 samples); *Charles H. Gilbert* cruise 18 (December 1954, 0 - 100 m., 21 samples); *Hugh M. Smith* cruise 27 (January 1955, 0 - 100 m., 32 samples); *Charles H. Gilbert* cruise 23 (September 1955, 0 - 140 m., 14 samples); and *Hugh M. Smith* cruise 30 (August - September 1955, 0 - 140 m., 106 samples). On *Hugh M. Smith* cruise 30, 20-minute 0- to 20-m. or 0- to 40-m. tows were taken in addition to the deeper tows.

Data on albacore caught by trolling are available from the above cruises of POFI vessels. We are indebted to the North Pacific Salmon Investigations of the Service, Seattle, Wash. for data on albacore caught in gill nets by the chartered vessels *Mitkof* and *Paragon* during the summer of 1955.

LABORATORY PROCEDURE

Following procedures defined by Hida and King (1955), a displacement volume measurement was obtained for each sample; "group counts" were made on samples from cruises 27 and 30 of the Smith and cruises 17 and 18 of the Gilbert. These counts were to major category only and not to the species level. The relative abundance of the individual species was evaluated in the following manner. The entire plankton sample, or aliquot in the case of large samples, was spread out in a dish, and from about 20 to 200 chaetognaths were removed, the number depending upon their abundance in the sample. The different species were identified, segregated, and, principally on the basis of our estimate of their absolute numbers in the sample, classified into one of four categories: conspicuously abundant, abundant, common, and present. For example, 230 chaetognaths were removed from the sample collected at station 8, cruise 17 of the Charles H. Gilbert; the number of each species and their abundance were classified as follows: 126 Sagitta bipunctata, conspicuously abundant; 66 S. serratodentata, abundant; 22 Pterosagitta draco, common; 10 S. hexaptera, common; 5 S. lyra, present; and 1 S. enflata, present.

Since they sink to the bottom of the collection jar, a representative sample of pteropods was easily obtained by decanting the sample until a rich concentrate of pteropods remained which was poured into a small dish, identified, and ranked in the same manner as were the chaetognaths.

The species distributions were classified into three categories, abundant, common, and present, and are summarized in tables 1 and 2. Since each summary evaluation was based on several, or many, samples the "conspicuously abundant" category was not applicable. Although this method of classification is only partially quantitative, we believe the results are sufficiently precise for the purposes of this study. It is our opinion that detailed species counts would not have made any significant changes in our evaluations.

Although most of the chaetognaths and pteropods were identified to species, there were a few unidentified forms which have been omitted from this report. Therefore the species listed were not necessarily the only ones present.

References used in identifying the chaetognaths were Dakin and Colefax (1940), Fowler (1906), Fraser (1952), Germain and Joubin (1916), Michael (1911), and Thomson (1947). For the pteropods the principal authority consulted was Tesch (1946, 1948).

RESULTS

While there were no obvious east-west differences in the distribution of the chaetognaths and pteropods, the north-south differences were marked. Three distinct subdivisions or faunal zones were evident from their distribution. The chaetognaths and pteropods identified from each of the zones are listed in tables 1 and 2. Pteropods were not studied as intensively as chaetognaths because it

Table 1.--Chaetognaths of the North Pacific and the faunal zones in which they occurred: data from Charles H. Gilbert cruises 17, 18, and 23 and Hugh M. Smith cruises 25, 27, and 30

* = present, ** = common, *** = abundant

Species	Zone		
	Subtropic	Transition	Subarctic
Pterosagitta draco (Krohn)	***	*	
Sagitta enflata (Grassi)	*		
S. robusta (Doncaster)	*		
S. hexaptera (d'Orbigny)	***	**	
S. serratodentata (Krohn)	***	**	
S. bipunctata (Quoy et Gaimard)	***	**	
S. minima (Grassi)	*	**	
S. lyra (Krohn)	**	***	*
S. elegans (Verrill)		*	***
Eukrohnia hamata (Möbius)		*	***
E. subtilis (Grassi)	**	*	

Table 2.--Pteropods of the North Pacific and the faunal zones in which they occurred: data from *Charles H. Gilbert* cruise 23 and *Hugh M. Smith* cruises 27 and 30

* = present, ** = common, *** = abundant

Species	Zone		
	Subtropic	Transition	Subarctic
Limacina inflata (d'Orbigny)	**	***	*
L. trochiformis (d'Orbigny)	**	*	
L. lesueuri (d'Orbigny)	**	**	
L. bulimoides (d'Orbigny)	*	*	
L. helicina (Phipps)		*	***
Creseis virgula (Rang)	**	*	
C. acicula (Rang)	***	*	
Cavolinia inflexa (Rang)	**	**	*
C. longirostris (Lesueur)	*		
C. tridentata (Forskål)	*	*	*
Cuvierina columnella (Rang)	*	*	
Hyalocylix striatia (Rang)	*	*	
Euclio pyramidata (Linne')	*	*	*
E. cuspidata (Bosc)	*	*	
E. balatium (Rang)		*	*
Styliola subula (Quoy et Gaimard)	**	*	
Peraclis apicifulva (Meisenheimer)		*	
P. reticulata (d'Orbigny)	*	*	
Diacria trispinosa (Lesueur)	*	*	
D. quadridentata (Lesueur)	**	*	
"*Cleodora compressa*" (Souleyet)	*	*	
"*Cleodora pygmaea*" (Boas)	*	*	
"*Hyalaea laevigata*" (d'Orbigny)	*		
"*Pleuropus longifilis*" (Troschel)		*	

(Note: Cymbulidae and naked pteropods not identified)

became evident that most of them were generally distributed, the species composition changing only slightly among the several zones.

General Abundance and Distribution

A preliminary study of the plankton samples from *Hugh M. Smith* cruise 30 has shown that regardless of time of day of hauling, oblique hauls between the surface and 40 m. yielded larger numbers of chaetognaths and pteropods per $m.^3$ of water strained than deeper hauls between the surface and 140 m. (table 3). A similar relation to depth was found in the tropical Pacific (Hida and King 1955) and in the North Pacific (Brodskii 1955).

Table 3.--Variation in number (no./1000 $m.^3$) of chaetognaths and pteropods with depth and time of hauling for the three faunal zones, as found on *Hugh M. Smith* cruise 30

	Subtropic		Transition		Subarctic	
	0-40 m.	0-140 m.	0-40 m.	0-140 m.	0-40 m.	0-140 m.
Chaetognaths						
Day	3,114	1,044	1,062	538	2,083	1,184
Night	2,671	1,461	1,591	1,440	5,836	4,807
Pteropods						
Day	309	219	185	177	314	199
Night	1,372	423	407	211	2,700	960

The number of chaetognaths and pteropods per cubic meter of water varied greatly among samples. The highest number of chaetognaths per unit of water strained was found in the Subarctic Zone and the highest number of pteropods per unit of water strained was found in the Transition Zone. The chaetognaths composed on the average 14 percent of the total number of net macroplankton taken in the Subtropic Zone, 8 percent in the Transition Zone, and 6 percent in the Subarctic Zone. The pteropods composed on the average 3 percent of the total number of organisms in the Subtropic Zone, 9 percent in the Transition Zone, and 1 percent in the Subarctic Zone.

Subtropic Zone

The area immediately north of the Hawaiian Islands, which we have designated the Subtropic Zone, was characterized by a great diversity of species and relatively low biomass (fig. 1). As shown in tables 1 and 2, at least 9 species of chaetognaths and 17 species of pteropods were

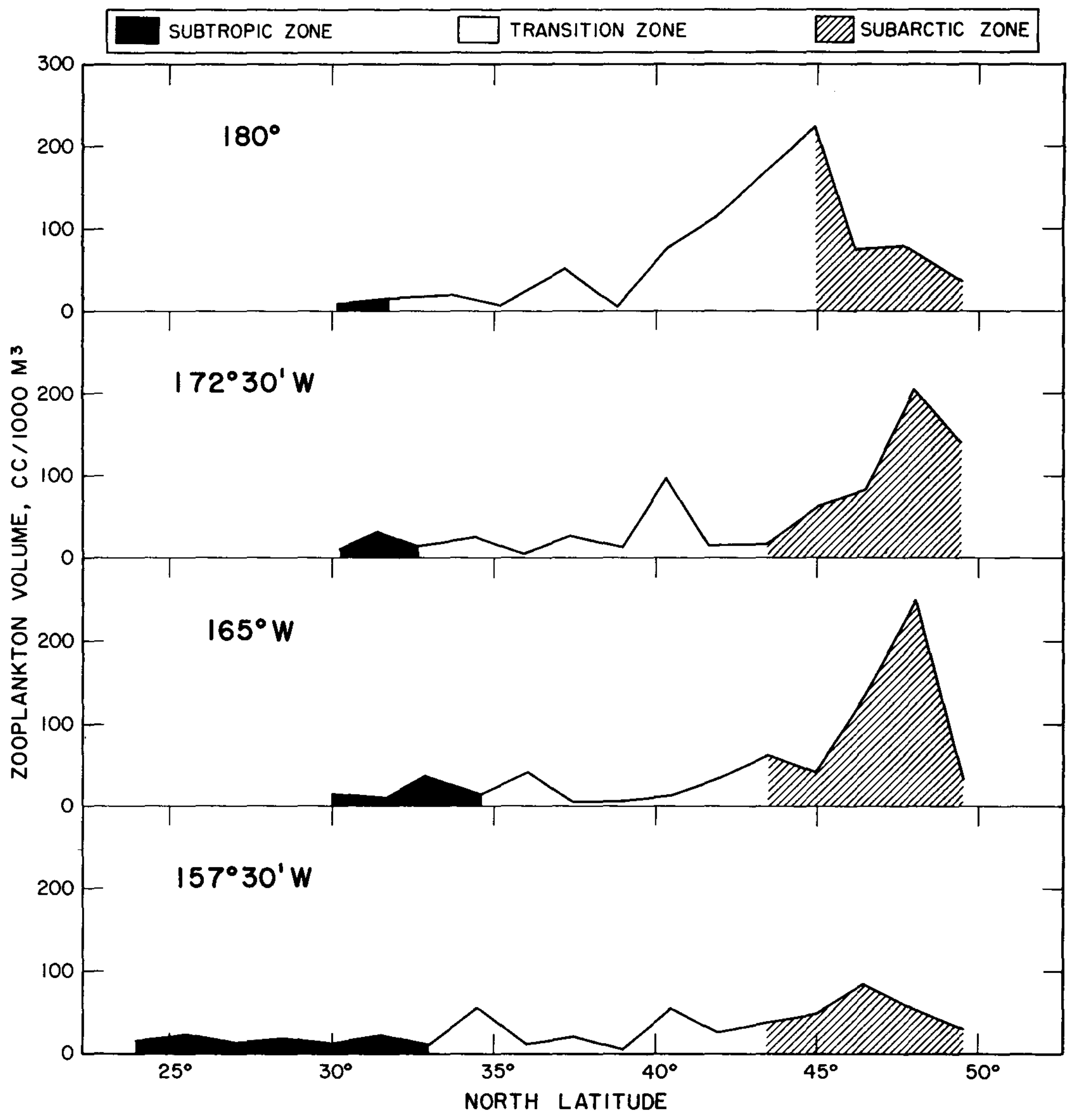


Figure 1.--Variations in the volume (cc./1000m.^{3}) of zooplankton among the Subtropic, Transition, and Subarctic Zones as found on Hugh M. Smith cruise 30, in July - August 1955.

present. Four species of chaetognaths, P. draco, S. hexaptera, S. serratodentata, and S. bipunctata and 1 species of pteropod, Creseis acicula, were classed as abundant. Two species of chaetognaths, S. lyra and Eukrohnia subtilis, and 7 species of pteropods, Limacina inflata, L. trochiformis, L. lesueuri, Creseis virgula, Cavolinia inflexa, Styliola subula, and Diacria quadridentata were classed as common.

The northern limits of the zone were drawn where P. draco ceased to be a common constituent of the plankton (table 4, fig. 2). P. draco was selected as the best indicator of this zone

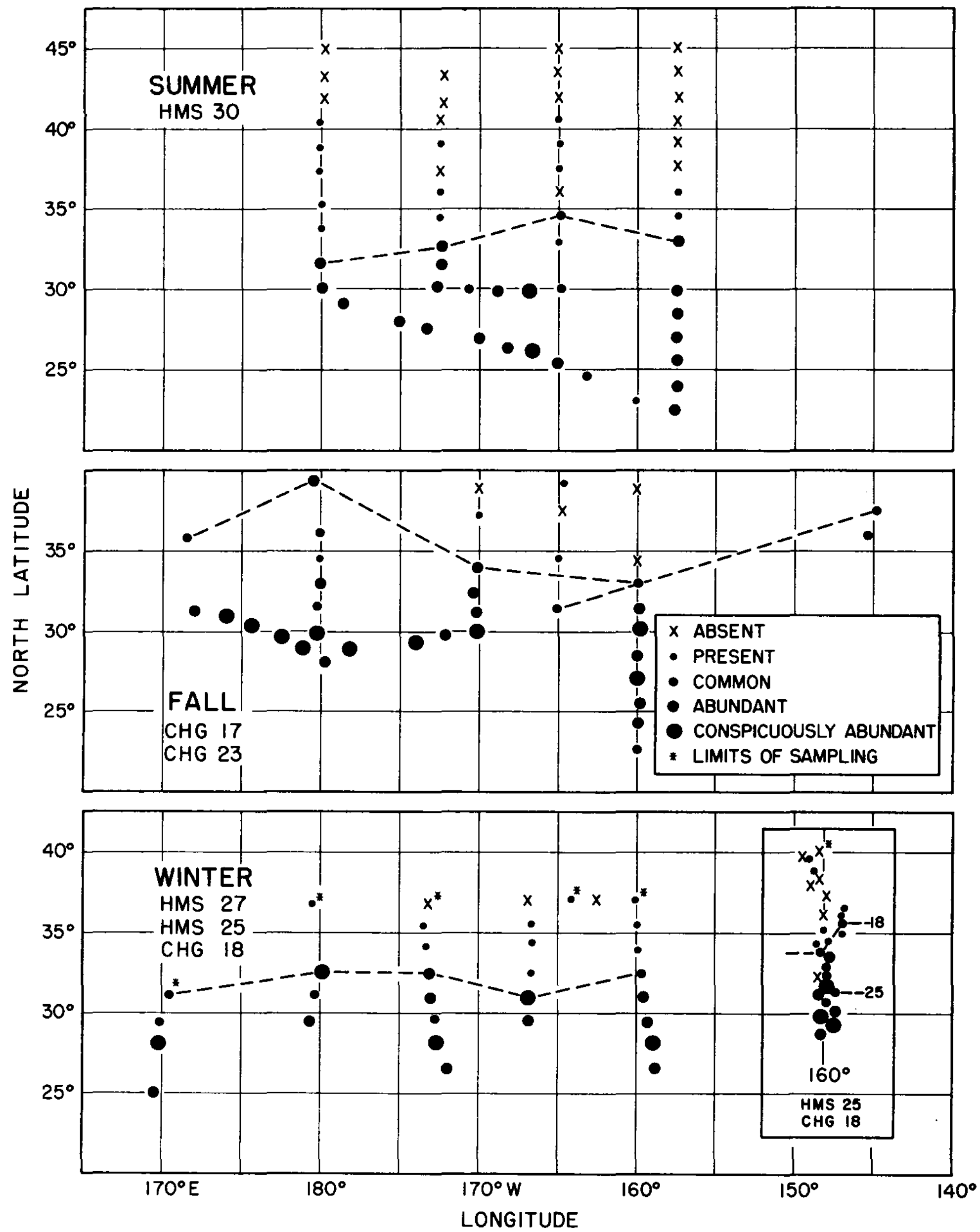


Figure 2.-- Seasonal variation in the northern limits of the Subtropic Zone (dashed line) as defined by the abundance of Pterosagitta draco. The symbols indicate the relative abundance of this species at each station where it occurred in the plankton collections.

Table 4.--Seasonal variation in the distribution of Pterosagitta draco with associated surface temperatures and salinities

* = limits of sampling

Season	Common south of Latitude Longitude	Surface Temp. °F.	Sal.‰	Northern limit Latitude Longitude	Surface Temp. °F.	Sal.‰
Fall 1954 GHG-17	32°57'N. 159°55'W.	77.0	34.74	32°57'N. 159°55'W.	77.0	34.74
	34°05'N. 170°11'W.	72.0	34.42	37°07'N. 170°00'W.	ca. 68.0	34.05
	39°28'N. 179°37'E.	ca. 58.0	34.07	39°28'N. 179°37'E.	ca. 58.0	34.07
	35°44'N. 171°31'E.	ca. 68.0	34.38	35°44'N. 171°31'E.	ca. 68.0	34.38
Winter 1954 CHG-18	33°46'N. 160°00'W.	ca. 63.0	-	39°41'N. 161°08'W.*	54.0	-
Winter 1955 HMS-27	32°34'N. 179°56'W.	65.3	34.94	36°43'N. 179°28'E.*	59.0	34.56
	32°30'N. 173°02'W.	61.3	34.65	35°20'N. 173°27'W.	57.6	34.47
	30°57'N. 166°49'W.	67.0	35.32	35°30'N. 166°40'W.	55.3	34.31
	32°26'N. 159°30'W.	60.8	34.58	36°56'N. 160°05'W.*	55.1	34.22
Summer 1955 HMS-30	31°43'N. 179°56'E.	78.7	35.12	40°19'N. 179°54'W.	66.1	34.06
	32°36'N. 172°27'W.	76.1	34.87	39°00'N. 172°30'W.	71.0	34.14
	34°38'N. 164°41'W.	76.0	34.82	40°27'N. 165°00'W.	71.7	34.05
	32°57'N. 157°29'W.	75.5	35.08	35°58'N. 157°30'W.	76.1	34.51
Fall 1955 CHG-23	31°23'N. 165°06'W.	76.3	35.21	39°04'N. 164°36'W.	70.0	34.34
	37°32'N. 144°43'W.	68.0	34.31	37°32'N. 144°43'W.	68.0	34.31
Winter 1954 HMS-25	31°12'N. 159°59'W.	65.2	34.93	34°05'N. 159°48'W.	60.9	34.31

since it was the only species that was consistently abundant. It is possible that the use of other species of chaetognaths and pteropods might have changed the boundaries to some degree. Although our data are incomplete with respect both to area and to season, the position of the northern boundary of the Subtropic Zone appears to shift latitudinally with the season and to vary somewhat with longitude. During both the winter and the summer periods (fig. 2) the boundary was confined between 31°N. and 34°30'N. latitude for the longitudes sampled. It showed the widest latitudinal variation in the fall, when it ranged from 31°12'N. to 39°28'N. between longitudes 145°W. and 170°E. Similar results were obtained by Beklemishev and Semina (1956).

The summer temperatures at the northern limits of the zone ranged from 75.5°F. to 78.7°F. with salinities from 34.82‰ to 35.32‰.[1] The winter temperatures ranged from 60.8°F. to 67°F. and salinities from 34.58‰ to 35.12‰. On the average the temperature difference between summer and winter conditions at the northern limits of this zone was about 13°F., with salinities remaining fairly stable. In the fall temperatures varied from 58°F. to 77°F. and salinities were as low as 34.07‰. This environmental instability during the fall months was perhaps due to the extremely changeable and generally adverse weather conditions prevailing in the area at that time of year. The temperature and salinity data at the northern limits of this zone are included in table 4.

Transition Zone

An area of mixed fauna and variable biomass (fig. 1) between the Subtropic and Subarctic Zones was arbitrarily designated the Transition Zone (tables 1 and 2). The fauna near its southern boundary resembled that of the Subtropic Zone with a decrease in abundance of the four abundant Subtropic Zone chaetognaths, particularly P. draco but also S. hexaptera, S. serratodentata, and S. bipunctata, and an

[1] All temperature and salinity data given in this paper are surface values, except for those of figure 4.

increase from common to abundant in the case of S. lyra. Among the pteropods most of the species found in the Subtropic Zone were also present in the Transition Zone, with a noticeable increase in L. inflata from common to abundant and a noticeable decrease in C. acicula from abundant to present. Near its northern boundary the fauna resembled that of the Subarctic Zone to some extent, with the appearance of the two chaetognaths S. elegans and E. hamata and the pteropod L. helicina. Only a few specimens of the pteropods E. balatium and P. apicifulva, which were not found in the Subtropic Zone, were found in this zone, and the pteropod Cavolinia longirostris, which was present in the Subtropic Zone, was not found here.

The Transition Zone was usually characterized by the abundance of the chaetognath S. lyra and the common occurrence of S. minima. Concerning S. minima, Pierce (1953), in his study of the chaetognaths over the continental shelf of North Carolina, stated that this species occurred in greater abundance in a region of mixing of different water masses. S. minima was classed as "common" in the Transition Zone (table 1), but it occurred in abundance in several localities; whereas it was scarce or lacking in the other two zones. Limacina inflata, which was listed as common in nearly all of the samples from the Subtropic Zone, occurred in abundance in several samples from the Transition Zone, particularly near its northern boundary.

Some of the samples collected in this zone were very poor both in species and in volume, containing very few copepods, chaetognaths, and pteropods, but an unusually large percentage of a heteropod, Atlanta sp.

The northern boundary of the Transition Zone, that is, the southern boundary of the Subarctic Zone, was defined when the chaetognaths S. elegans or E. hamata were found to be common in a sample. Figure 3 and table 5 show that the boundary fluctuated slightly with change in longitude in the summer and fall, occurring between 43°N. and 45°N. latitude on most longitudes, with the boundary slightly farther north in the fall than in the summer. Sampling was not continued far enough north to define the northern boundary of the Transition Zone in winter, but indications are that the boundary moved slightly to the south. The southern boundary of this zone coincides with the northern boundary of the Subtropic Zone so it will not be redefined. The Transition Zone lay roughly between 33°N. and 45°N. latitudes during fall and summer, with surface temperatures ranging from 78.8°F. to 47.3°F. from south to north, and surface salinities from 35.00‰ to 33.60‰.

Subarctic Zone

The northernmost subdivision of the area, the Subarctic Zone, was characterized by a marked decrease in species diversity for both chaetognaths and pteropods (tables 1 and 2) and great increase in biomass (fig. 1). The high biomass (fig. 1) may be attributed to "blooms" of copepods, euphausiids, and at times radiolarians and diatoms (McGary et al. 1956, table 7). The southern limit of this zone was defined by the occurrence in abundance of the two cold water chaetognaths S. elegans or E. hamata, as explained in the previous section. L. helicina was the most abundant pteropod found in this zone; L. inflata, E. pyramidata, E. balatium, C. inflexa, and C. tridentata were also present. Salinities in the Subarctic Zone were usually less than 33.60‰ and temperatures lower than 68.4°F. in summer, whereas in the fall salinities of less than 33.22‰ and temperatures lower than 47.3°F. were encountered.

Fauna and Temperature-Salinity Relations

The temperature-salinity (T-S) relation for each station along the eastern and western meridional sections of Hugh M. Smith cruise 30 is shown in figure 4[2/], together with the relation of the faunal zones to the North Pacific water types (the western North Pacific Central Water mass and the Subarctic Water mass) as redrawn from Sverdrup et al. (1942: 741). The shape of the temperature-salinity curve describes the character or identity of the water mass at each station (Sverdrup et al. 1942: 142). The spread in the curves in the upper 200 meters of depth (towards the higher temperatures in fig. 4) is of particular importance to this study. There is a natural segregation of the curves into three groups: one with lower salinities and lower temperatures characteristic of the Subarctic Water mass; a second with higher salinities and higher temperatures, features identifying the Pacific Central Water mass; and an intermediate group characteristic of the North Pacific Current.

2/ To construct this figure the observed data were plotted according to a new method described by Hans T. Klein in an unpublished manuscript "A new technique for processing physical oceanographic data," Scripps Institution of Oceanography.

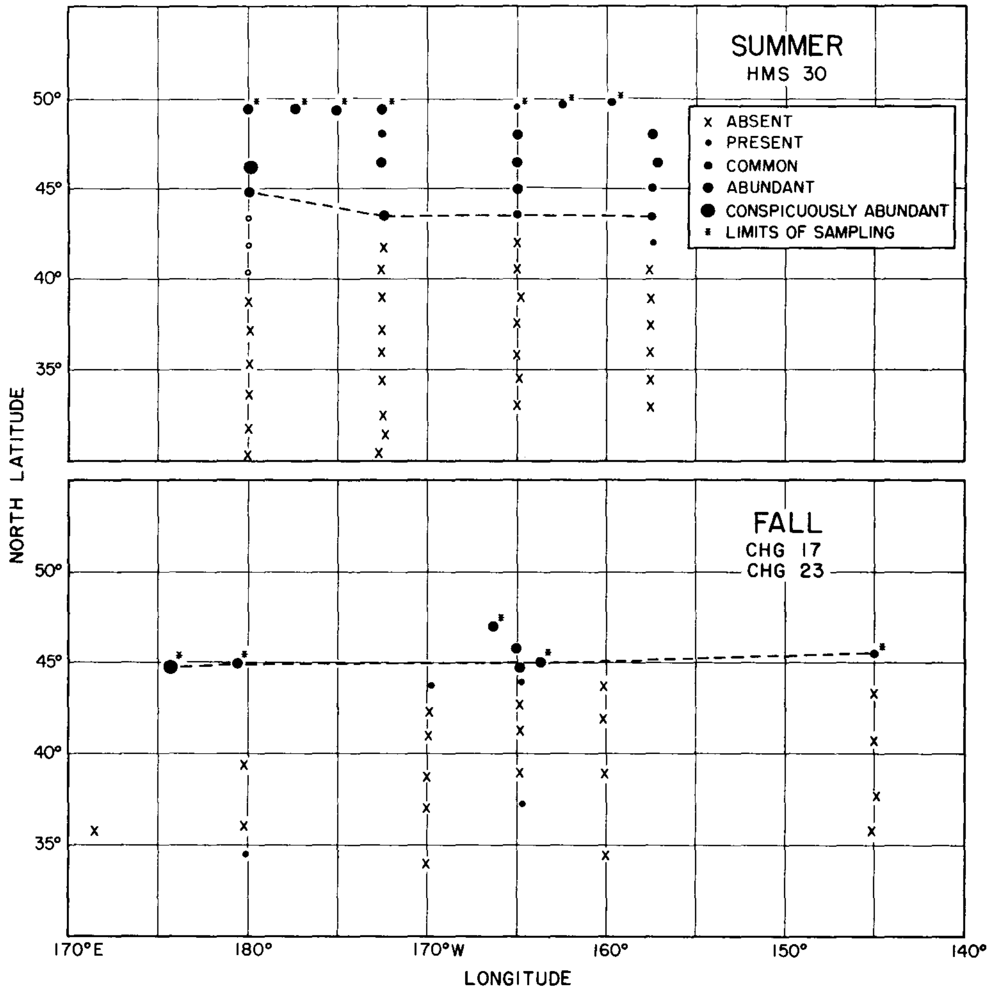


Figure 3.--Seasonal variation in the northern limits of the Transition Zone (dashed line) as defined by the abundance of Sagitta elegans or Eukrohnia hamata. The symbols indicate the abundance of the species in that locality.

In general, the chaetognaths and pteropods characteristic of the Subtropic Zone centered about water types with temperatures of about 76°F. (24°C.) and salinities of about 35‰ corresponding to the Pacific Central Water mass, those of the Transition Zone at temperatures of about 71°F. (22°C.) and salinities of about 34‰ corresponding to the North Pacific Current, and those of the Subarctic Zone at temperatures of about 58°F. (14°C.) and salinities of about 33‰ corresponding to the Subarctic Water mass. Figure 4, for the two meridians, shows that the change in temperature-salinity values between the Subtropic and Transition Zones was a gradual one while the change between the Transition and the Subarctic Zones was quite abrupt for the 180° meridian and less so for the 157°30'W. meridian. These same features were generally evident in the chaetognath distribution (fig. 5), thus demonstrating that the differences between regions defined on the basis of fauna were also evident in the characteristics of the water. On the basis of the T-S diagrams and the chaetognath data, the southern boundary of the Subarctic Zone is defined more sharply on the westernmost longitudes (180°) than to the east (157°30'W.), agreeing with Sverdrup et al. (1942: 143).

Relation to Surface Albacore Distribution

Initial study of troll and gill-net catches of albacore in the North Pacific in relation to the zones established on the basis of the chaetognath and pteropod distribution indicated that these fish were found in all three zones during the periods covered by our data. In the summer of 1955, albacore were caught in the Subarctic and

Table 5.--Seasonal variation in the distribution of Sagitta elegans and Eukrohnia hamata with associated surface temperatures and salinities

Season	Common north of		Surface	Sal.‰	Southern limit		Surface	Sal.‰
	Latitude	Longitude	Temp. °F.		Latitude	Longitude	Temp. °F.	
S. elegans								
Fall 1954	45°03'N.	163°45'W.	59.9	33.06	43°47'N.	169°43'W.	57.2	33.33
GHG-17	44°59'N.	179°28'E.	49.1	33.42	44°59'N.	179°28'E.	49.1	33.42
	44°56'N.	175°45'E.	47.3	33.22	44°56'N.	175°45'E.	47.3	33.22
Summer 1955	44°57'N.	179°51'W.	55.5	33.24	41°50'N.	179°56'W.	61.7	33.95
HMS-30	43°27'N.	172°20'W.	63.7	33.60	43°27'N.	172°20'W.	63.7	33.60
	44°57'N.	165°00'W.	64.2	33.03	43°30'N.	164°59'W.	68.4	33.30
	44°59'N.	157°25'W.	61.4	33.09	43°27'N.	157°25'W.	65.6	33.48
Fall 1955	47°23'N.	166°14'W.	53.5	32.66	37°12'N.	164°39'W.	ca. 72.0	34.31
CHG-23	45°29'N.	144°57'W.	53.3	32.77	45°29'N.	144°57'W.	53.3	32.77
E. hamata								
Fall 1954	45°03'N.	163°45'W.	59.9	33.06	43°47'N.	169°43'W.	57.2	33.33
CHG-17	44°56'N.	175°45'E.	47.3	33.22	34°31'N.	179°52'E.	71.6	34.22
Summer 1955	44°57'N.	179°51'W.	55.5	33.24	40°18'N.	179°57'W.	66.1	34.06
HMS-30	43°27'N.	172°20'W.	63.7	33.60	43°27'N.	172°20'W.	63.7	33.60
	43°30'N.	164°59'W.	68.4	33.30	43°30'N.	164°59'W.	68.4	33.30
	43°27'N.	157°25'W.	65.6	33.48	41°58'N.	157°23'W.	68.9	33.86
Fall 1955	45°52'N.	165°00'W.	ca. 55.2	32.81	37°12'N.	164°39'W.	ca. 72.0	34.31
CHG-23					45°29'N.	144°57'W.	53.3	32.77
Winter 1954					37°00'N.	150°55'W.	56.1	33.91
HMS-25					37°02'N.	154°54'W.	55.1	33.91
					38°31'N.	147°00'W.	54.9	33.62

Transition Zones by the Hugh M. Smith, the Mitkof, and the Paragon (fig. 6). In the fall on Charles H. Gilbert cruises 17 and 23 (fig. 6) they were taken in the Transition and Subtropic Zones, and in winter on Hugh M. Smith cruise 27 (fig. 6) they were taken in the Subtropic Zone near its northern boundary. It has been noted that the albacore are distributed in respect to certain isotherms and are not restricted to any one current or water mass (Shomura and Otsu 1956, Graham 1957); insofar as the chaetognath zones are concerned the albacore seem to shift from the Subarctic Zone in summer southward to the Subtropic Zone in winter, and are not distributed in respect to particular water types or plankton complexes.

SUMMARY AND CONCLUSIONS

1. On Hugh M. Smith cruise 30 larger catches, as number per unit of water strained, of *chaetognaths and pteropods* were taken in the shallow (0 - 40 m.) hauls than in the deeper (0 - 140 m.) hauls both during the day and at night. The chaetognaths occurred in greatest abundance in the Subtropic Zone; the pteropods were an important constituent of the plankton in both the Subtropic and the Transition Zones.

2. The chaetognaths and pteropods of the central North Pacific could be segregated according to species composition into three faunal zones:

   a. The Subtropic Zone, as defined by the abundance of the chaetognath Pterosagitta draco, was a region of great species diversity with relatively low biomass and characterized by relatively high temperatures and salinities. The boundaries of this zone were essentially the same in winter as in summer but fluctuated widely in the fall.

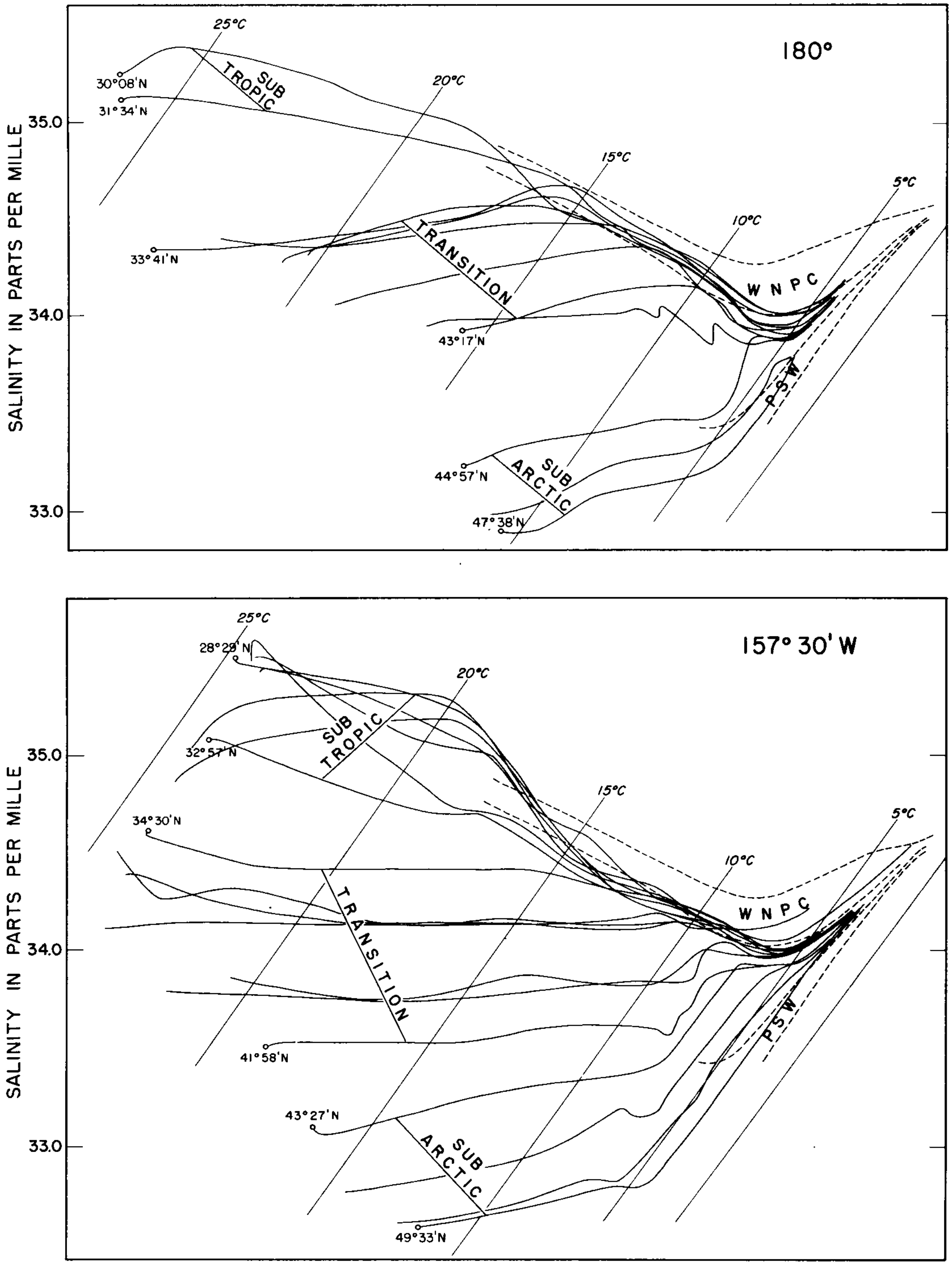


Figure 4.--Temperature-salinity relations for the eastern and western meridional sections of Hugh M. Smith cruise 30. The diagrams were grouped into three water types according to the distribution of chaetognaths. The temperature-salinity relation (indicated with dashed lines) for the Western North Pacific Central Water mass (WNPC) and the Pacific Subarctic Water mass (PSW), as redrawn from Sverdrup et al. (1942) were superimposed on the diagrams for Hugh M. Smith cruise 30 to identify the water types.

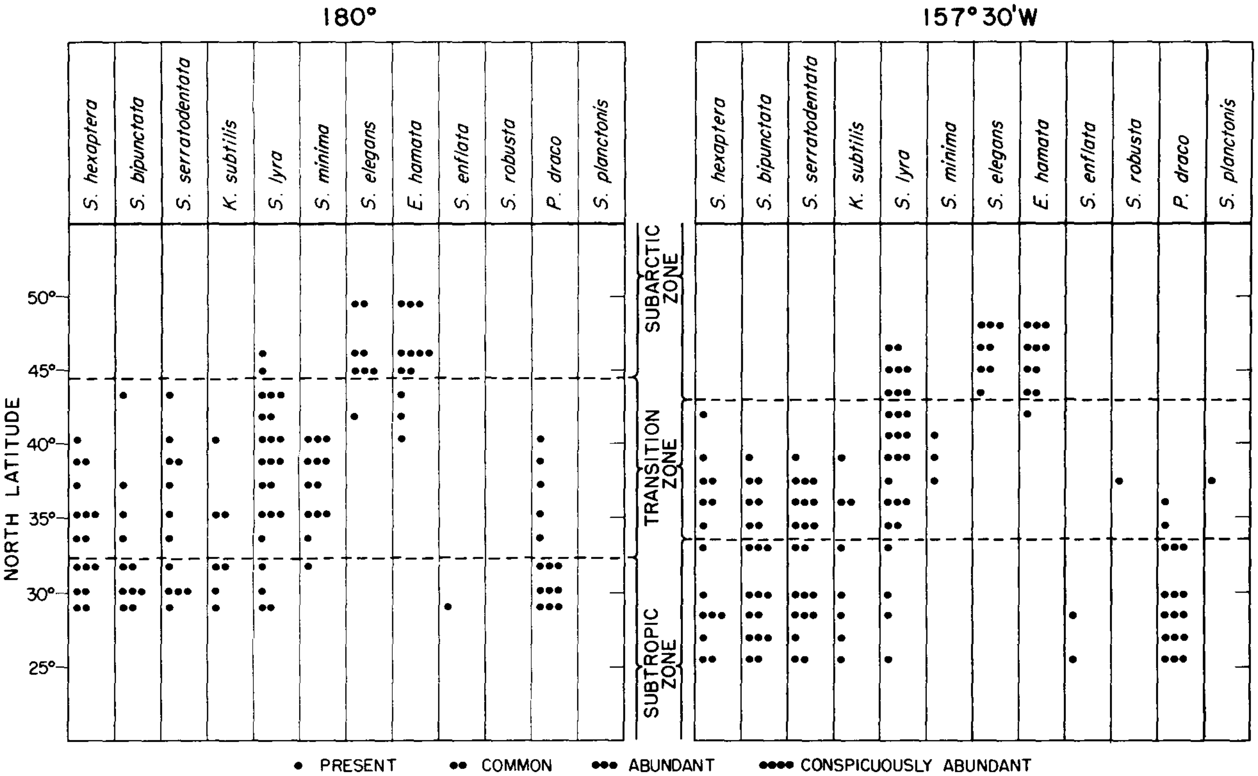


Figure 5.--Comparison of the distribution of chaetognaths along the 180° and 157°30'W. meridians as found on Hugh M. Smith cruise 30.

b. The Transition Zone which lay between the Subtropic and the Subarctic Zones was a zone of mixed chaetognath and pteropod fauna with highly variable biomass and intermediate values of temperature and salinity. The chaetognath Sagitta lyra and the pteropod Limacina inflata occurred here in greatest abundance. The chaetognath Sagitta minima was abundant only in this zone and scarce or lacking in the other zones.

c. The Subarctic Zone, as indicated by an abundance of the chaetognaths Sagitta elegans or Eukrohnia hamata and the pteropod Limacina helicina, was an area of high biomass with very little species diversity, and was characterized by cooler and less saline waters. The southern limits of this zone remained fairly stable in summer and fall, but there were indications that it moved southward in winter.

3. Examination of temperature-salinity relations in the central North Pacific, employing data obtained coincident with the plankton collections, showed the presence of three types of water: (a) Subarctic Water of relatively low temperatures and salinities, (b) Pacific Central Water of higher temperatures and salinities, and (c) a band in between with water of intermediate character. The boundaries of these three types of water corresponded in all essential respects to those of the Subarctic, Subtropic, and Transition faunal zones established on the basis of chaetognath and pteropod distribution.

4. Indications are that surface albacore are not confined to a particular type of water as defined by the distribution of chaetognaths and pteropods and the temperature-salinity characteristics, but are rather associated with certain surface isotherms. In summer the albacore were found in the Subarctic and Transition Zones, in fall they occurred in the Transition and Subtropic Zones, and in winter they were found in the Subtropic Zone.

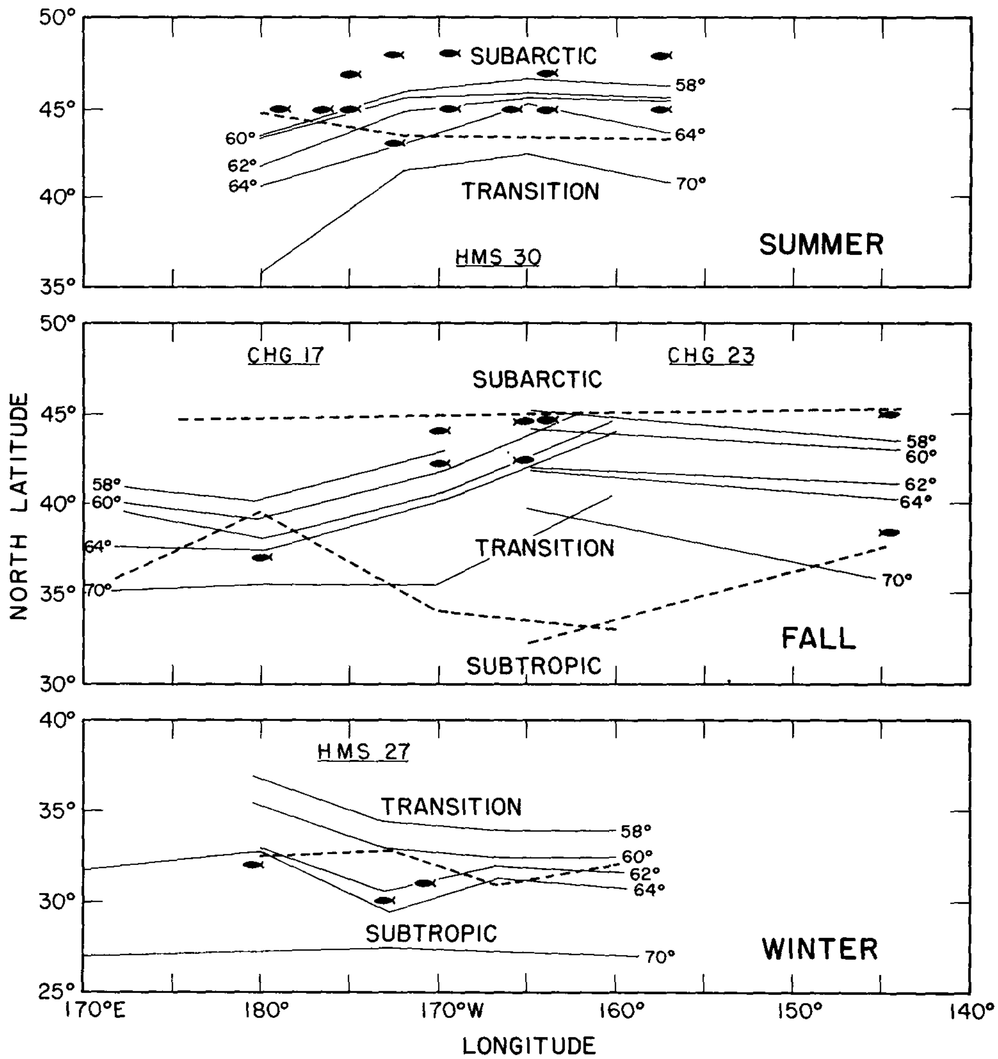


Figure 6.--The 58°, 60°, 62°, 64°, and 70°F. isotherms plotted for summer, winter, and fall together with the distribution of surface-caught albacore in respect to the faunal zones.

LITERATURE CITED

BEKLEMISHEV, K. V., and G. L. SEMINA
1956. On the structure of the biogeographical boundary between the boreal and tropical regions in the pelagial of the northwestern Pacific Ocean. Doklady Akademii Nauk. U.S.S.R. Vol. 108, No. 6, p. 1057-1060. (In Russian; translated by W. G. Van Campen)

BIGELOW, HENRY B.
1928. Plankton of the off-shore waters of the Gulf of Maine. U. S. Bur. Fish., Bull. 40(2): 1-509.

BRODSKII, K. A.
1955. Plankton of the northwestern part of the Kuroshio and the waters of the Pacific adjacent to the Kurile Islands. Academy of Sciences of the U.S.S.R., Trans. Inst. of Oceanology 18: 124-133. (In Rûssian ; translated by W. G. Van Campen)

DAKIN, WILLIAM J., and A. N. COLEFAX
1940. The plankton of the Australian coastal waters off New South Wales. Part I. U. of Sydney, Dept. of Zool. Monogr. 1: 63-70.

FOWLER, GEORGE H.
1906. The Chaetognatha of the "Siboga" expedition with a discussion of the synonymy and distribution of the group. "Siboga" Exped. Monogr. 21: 1-86.

FRASER, J. H.
1952. The Chaetognatha and other zooplankton of the Scottish area and their value as biological indicators of hydrographical conditions. Scottish Home Dept., Mar. Res. (2): 1-52.

GERMAIN, L., and L. JOUBIN
1916. Chétognathes provenant des campagnes des yachts "Hirondelle" et "Princesse-Alice." Res. Camp. Sci. Monaco, Fasc. XLIX: 1-119.

GRAHAM, JOSEPH J.
1957. Central North Pacific albacore surveys, May to November, 1955. U. S. Fish and Wildlife Service, Spec. Sci. Rept.--Fish. 212, 38 p.

HIDA, THOMAS S., and J. E. KING
1955. Vertical distribution of zooplankton in the central equatorial Pacific, July-August 1952. U. S. Fish and Wildlife Service, Spec. Sci. Rept.--Fish. 144, 22 p.

KING, JOSEPH E., and JOAN DEMOND
1953. Zooplankton abundance in the central Pacific. U. S. Fish and Wildlife Service, Fish. Bull. 54(82): 111-144.

McGARY, JAMES W., E. C. JONES, and T. S. AUSTIN
1956. Mid-Pacific oceanography Part IX, Operation NORPAC. U. S. Fish and Wildlife Service, Spec. Sci. Rept.--Fish. 168, 127 p.

MICHAEL, ELLIS L.
1911. Classification and vertical distribution of the Chaetognatha of the San Diego region, including redescriptions of some doubtful species of the group. Univ. Calif. Publ. Zool. 8(3): 21-186.

MOORE, HILARY B.
1949. The zooplankton of the upper waters of the Bermuda area of the North Atlantic. Bull. Bingham Oceanogr. Coll. 12(2): 1-97.

PIERCE, EMORY L.
1953. The Chaetognatha over the continental shelf of North Carolina with attention to their relation to the hydrography of the area. Jour. Mar. Res. 12(1): 75-92.

RUSSELL, F. S.
1939. Hydrographical and biological conditions in the North Sea as indicated by plankton organisms. Cons. Int. Explor. Mer., Jour. du Cons. 14(2): 171-192.

SHOMURA, RICHARD S., and T. OTSU
1956. Central North Pacific albacore surveys, January 1954 - February 1955. U. S. Fish and Wildlife Service, Spec. Sci. Rept.--Fish. 173, 29 p.

SVERDRUP, HARALD U., M. W. JOHNSON, and R. H. FLEMING
1942. The oceans, their physics, chemistry and general biology. New York: Prentice Hall, Inc., 1087 p.

TESCH, J. J.
1946. The thecosomatous pteropods, I. The Atlantic. Carlsberg Foundation's Oceanographical Exped. Round the World 1928-30, "Dana" Rept. No. 28: 1-82.

1948. The thecosomatous pteropods, II. The Indo-Pacific. Carlsberg Foundation's Oceanographical Exped. Round the World 1928-30, "Dana" Rept. No. 30: 1-45.

THOMSON, J. M.
1947. The Chaetognatha of south-eastern Australia. Coun. Sci. Ind. Res. Org. (Australia), Bull. No. 222: 1-43.